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16. ABSTRACT

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WASTEWATER TREATMENT FOR REUSE AND ITS CONTRIBUTION TO WATER SUPPLIES

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the projects of that research; a most vital communications link between the researcher and the user community.

The study summarized in this report evaluates a combined biological/physical-chemical pilot treatment system designed to produce a high quality reusable water. Process reliability is established and effluent constituents are related to similar materials identified in finished drinking waters.

Francis T. Mayo
Director
Municipal Environmental Research Laboratory

ABSTRACT

An 18 month study using cost effective municipal wastewater treatment technology coupled with a computerized data handling system, was conducted at the EPA/Washington, D.C. Blue Plains Pilot Plant to obtain data on the safety of the effluent for discharge upstream of drinking water intakes, and for potential domestic reuse purposes. Treatment reliability was demonstrated and performance results showed the absence of virus in the effluent. Effluent concentrations of radioactivity, trihalomethanes and other volatile organics, heavy metals, pesticides, TOC, turbidity, general inorganic compounds, and pathogenic indicator organisms were shown to be similar to those found in finished drinking waters during the EPA National Organics Reconnaissance Survey in 1975. The specific organic compounds identified in the effluent are also present in finished drinking waters. Effluent organic concentrates did not exhibit mutagenic properties, and results of an 80 element survey did not detect the presence of significant quantities of any hazardous inorganic material. Effluent endotoxin levels were comparable to levels in public drinking water supplies.

This report was submitted in partial fulfillment of contract No. 68-03-0344 by the District of Columbia Pilot Plant under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from April 1975 to September 1976.

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SECTION 1

INTRODUCTION

We are living in a Nation where millions of people are presently reusing wastewater indirectly for domestic purposes. Severe contamination of many surface supplies has occurred, as evidenced by the identification of carcinogenic organic materials in finished drinking waters, and increasing instances of groundwater contamination are being found. There is a concern on the part of health agencies in areas that use surface supplies for domestic purposes as to the potential hazards of the present covert reuse of wastewater discharged upstream of drinking water intakes. Since the typical wastewater treatment plant does not remove all of the contaminants from the wastewater there is a basis for this concern, and thus a need to know the appropriate levels of municipal treatment to ensure the safety of water supply intakes in the vicinity of the discharges.

The concerns of health agencies where covert reuse is prevalent are also receiving attention by health agencies in the more arid areas of the U.S. where water utilities are proposing the overt domestic reuse of wastewater to supplement depleted groundwater supplies and unreliable surface sources. Concerns about both covert and overt reuse are the same since the problems and the research data required to solve the problems are the same. The questions that need answers are:

- What are the health effects of the covert/overt reuse of wastewater?
- What technology is needed to remove potential hazardous materials?

The Environmental Protection Agency (EPA) through its Municipal Environmental Research Laboratory (MERL) in Cincinnati, Ohio is addressing the technology question by characterizing the ability of municipal wastewater treatment systems to remove pollutants of health concern and providing knowledge of treatment system performance variability and reliability.

A combined biological/physical-chemical treatment system designed to produce a high quality reusable water has been in operation at MERL's Washington, D.C. Pilot Plant for 18 months as part of a project that had the following objectives:

- Identification of specific pollutants in the final effluent and evaluation of the performance of the individual processes in removing these pollutants.

- Provide data on process and system performance variability and reliability with respect to pollutant removals.

SECTION 2

CONCLUSIONS

Performance results showed the absence of virus in the effluent, and concentrations of radioactivity, trihalomethanes and other violatile organics, heavy metals, pesticides, TOC, turbidity, and microbiological parameters similar to those found in finished drinking waters during the EPA National Organics Reconnaissance Survey in 1975. The specific organic compounds identified in the effluent are also present in finished drinking waters. Effluent organic concentrates did not exhibit mutagenic properties and results of an 80 element survey did not detect the presence of significant quantities of any hazardous inorganic material. Effluent endotoxin levels were comparable to levels in public drinking water supplies.

Treatment reliability was demonstrated as evidenced by the frequency distribution of the day to day concentrations of chemical, physical, and biological materials remaining in the effluent. In full scale facilities employing similar treatment processes and located upstream of drinking water intakes, or designed for domestic reuse purposes, reliability can be further enhanced by in-plant storage facilities to provide flexibility, process control instrumentation, and dedicated operating personnel. In planned reuse situations where a monetary value is set on the water, or where enforced legal restraints are placed on effluent quality reliability will become very good.

SECTION 3

DESCRIPTION OF TREATMENT SYSTEM

The treatment system was located on the grounds of the Washington, D.C. Blue Plains wastewater treatment facility and was supervised by MERL staff and operated in cooperation with the Washington, D.C. Department of Environmental Services. The system treated degritted D.C. municipal wastewater using a screening device to remove coarse materials, lime clarification, dispersed growth nitrification, fixed film denitrification, carbon adsorption, dual media filtration, and chlorination for disinfection. This sequence of processes was chosen because of past experience with the performance of the individual processes and compatibility of the unit processes when combined into a treatment system that could produce a reusable high quality water from municipal wastewater. Also, a similar treatment system was identified at a workshop on "Research Needs for the Potable Reuse of Municipal Wastewater" [1] as one of four treatment systems that had potential as a cost-effective treatment for potable reuse.

A schematic flow diagram of the treatment system is presented in Figure 1 and the design and operating conditions are summarized in Table 1. The system operates continuously at 35 gpm (2.2 l/s). The backwash water from the denitrification, carbon adsorption, and filtration processes are returned to the influent of the lime clarification processes. A portion of the sludges from the lime clarification and nitrification processes are wasted to maintain process equilibrium.

The treatment system was operated on a continuous basis with operators assigned to three, 8 hour shifts each day. Samples were taken manually by the operators and composited in refrigerated containers as required. Twenty-four hour composites were taken 5 days per week and no sampling was done between Friday 8 a.m. and Sunday 8 a.m. Other types of sampling were also done manually by the operators as required.

Establishing the reliability of any treatment system requires a long-term program of routine monitoring of the system performance. A mass of valuable data was obtained as a result of this program and an efficient computerized data storage and retrieval system was developed to sort large quantities of data per month from 37 performance or process monitoring stations. The data storage and retrieval system was designed for use on the EPA UNIVAC 1110 Computer located at EPA Research Triangle Park in North Carolina. All the programs run in batch or demand mode. The system is modular in design to allow the addition and modification of programs without affecting the system integrity. Data is entered into and withdrawn from the computer using a terminal hookup. Statistical reports, data listing, as well as data plots can be obtained as required by project personnel to aid in establishing the system performance credibility.

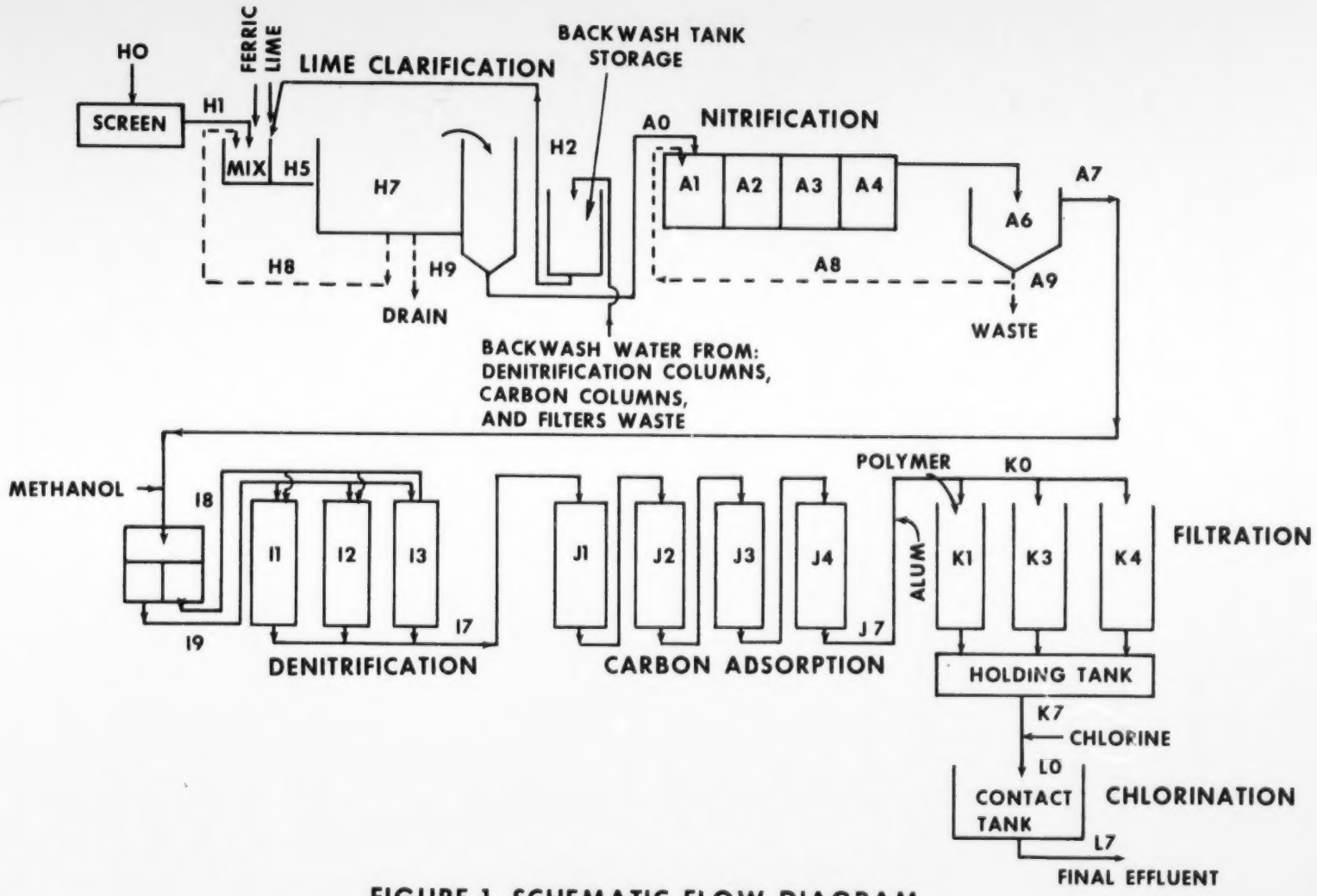

FIGURE 1. SCHEMATIC FLOW DIAGRAM

TABLE 1. DESIGN DATA AND OPERATING CONDITIONS

PARAMETER	VALUE
Raw Wastewater (Constant Flow)	35 gpm ($2.2 \times 10^{-3} m^3/s$)
Screening Device	
Type	Bauer Hydrasive Model 552
Size of Openings	0.040 in. (1.02 mm)
Lime Clarification	
Lime Dosage (pH 10.0) (as CaO)	200 mg/l
$FeCl_3$ Dosage (as Fe)	15 mg/l
Hydraulic Loading Rate	1050 gpd/sq.ft. ($42.8 m^3/m^2 d$)
Detention Time	2.7 hr.
Sludge Wasting Rate	2% to 3%
Percent Solids in Waste Sludge	1.5% to 2.0%
Nitrification (Suspended Growth)	
Detention Time	3.5 hr.
MLSS	2000 mg/l
SRT	8 day
Air Requirement	1450 cu.ft./lb BOD ($90.6 m^3/k_g$)
Clarifier Overflow Rate and Detention Time	526 gpd/sq.ft. ($21.4 m^3/m^2 d$) 2-3.6 hr.
Denitrification (Fixed Film)	
Media Size	3 to 6 mm
Specific Surface Area	245 sq.ft./cu.ft. ($900 m^2/m^3$)
Hydraulic Loading Rate	5.9 gpm/sq.ft. ($4.1 l/m^2 s$)
Methanol/NO_3-N Ratio	2:1 to 4:1

TABLE 1 (cont'd)

PARAMETER	VALUE
Bed Depth	15 ft. (4.6 m)
Detention Time (Empty Bed)	9.5 min.
Operation	Downflow Packed Bed
Granular Carbon Adsorption	
Detention Time (Empty Bed)	35 min.
Hydraulic Loading Rate	7 gpm/sq.ft. (4.8 l/m^2s)
Columns in Series	4
Carbon Size (Filtrasorb 300)	8 x 30 Mesh
Operation	Downflow Packed Bed
Filtration with Alum and Polymer	
Hydraulic Loading Rate	3 gpm/sq.ft. (2.04 l/m^2s)
Dual Media	
Coal 1.2-1.4 mm	2.0 ft. (0.61 m)
Sand 0.6-0.7 mm	1.0 ft. (0.30 m)
Alum	5 mg/l
Disinfection with Chlorine	
Detention Time	20 min.
Residual	1 mg/l Free Available

SECTION 4

PERFORMANCE

VIRUS

Virus in wastewater effluents are of concern to health agencies dealing with the use of contaminated surface drinking water supplies and proposed domestic reuse situations. For this reason it is important that virus analyses be included in any reuse technology monitoring program. Virus and other pathogens were monitored at various points in the treatment system on three occasions over a three month period using methods described by Rao, V.C., et al [2] and Wallace, C., et al [3].

Samples of the raw sewage, finished effluent, and dual media filtration effluent were taken during the first sampling period. As shown in Table 2 animal viruses in raw sewage samples ranged from about 7000 to more than 17,000 PFU/100 gal (1,850-4,500 PFU/100 l). No animal viruses were observed in the dual media filtration effluent before chlorination, or the finished effluent following concentration of 100-150 gal (379-568 l) of each effluent.

During the second and third months samples of the raw sewage, finished effluent and effluent from the nitrifying activated sludge were taken. Animal viruses in the raw sewage from 17,000 to 68,000 PFU/100 gal (4,500-18,000 PFU/100 l) and from 28,000 to 68,000 PFU/100 gal (7,400-18,000 PFU/100 l). Animal viruses were not detected in the final effluent in either sampling period. A total of 7 samples were concentrated during these periods ranging in volume from 50 to 238 gal (190-900 l). During the last two sampling periods, effluent from the nitrifying sludge system was tested on five occasions following concentration of 40 to 160 gal (151-605 l) of each system. In this phase of treatment, animal viruses still could not be detected. Assays were carried out on solids remaining on prefilters used for clarifying both the nitrification and final effluents. Viable animal viruses could not be detected after processing these solids.

RADIOACTIVITY

Samples of effluent were periodically taken for gross beta and gross alpha analyses and the results are summarized in Table 3. These levels are well below the maximum contaminant level set forth in the EPA Interim Primary Drinking Water Regulations [4] for radioactivity and they are comparable to those reported in finished drinking water supplies [5].

TABLE 2. VIRUS

Sampling Period	Animal Virus pfu/100 liters			
	PROCESS			
	Influent	Nitrification	Filtration	Chlorination
1	1,850 - 4,500	-	N.D.	N.D.
2	4,500 - 18,000	N.D.	-	N.D.
3	7,400 - 18,000	N.D.	-	N.D.

Sample Volumes - 189 liters to 900 liters

N.D. - None Detected

TABLE 3. RADIOACTIVITY

Sampling Period	Effluent Values pci/l	
	Gross Alpha	Gross Beta
1	< 0.3	7.9 ± 0.9
2	< 0.5	8.1 ± 0.9
3	< 0.5	7.4 ± 0.9
4	< 0.5	5.0 ± 0.9
Average in Drinking Water*	5.5	2.9

*Summary of Interstate Carrier Water Supply Radionuclide Data
"Preliminary Assessment of Suspected Carcinogens in Drinking Water"
EPA, December 1975.

VOLATILE ORGANICS

Four trihalomethanes, carbon tetrachloride, and 1, 2 - dichloroethane were determined in the influent and effluent from individual processes on a twice per month basis to determine the effectiveness of the treatment system in removing these materials. A summary of the influent and effluent concentrations of the compounds compared to the range of concentrations found in finished drinking water supplies is included in Table 4. Figure 2 shows the variation of the volatile organics through each process. Although the concentrations are quite low there is definite indication that chlorination increases the quantities of each of the six compounds.

Table 5 shows the results of analyses of other volatile organics in the pilot plant influent and in the effluent from various unit processes. The types of compounds and their corresponding concentrations are similar to those present in finished drinking water supplies [5]. Blanks in the tables indicate the compounds were below the detection limit of the GC/MS technique used [6].

TOXICITY SCREENING

Organic materials were concentrated from 500 gal (1,900 l) samples of effluent using a reverse osmosis technique that employed cellulose acetate and nylon membranes in series [7]. The concentrate from each type membrane was extracted with pentane or methylene chloride at acidic (pH 2) and neutral (pH 7) conditions. The separate extracts and a composite of the extracts were tested for mutagenicity using the Ames procedure [8] that utilizes *in vitro* microbiological assays with strains of *Salmonella Typhimurium* TA 98 and TA 100. No mutagenicity was detected as shown by the data in Table 6.

Table 7 shows the results of bacterial endotoxin tests on effluent samples as compared to similar data from ten public drinking water systems. These results were reported by Jorgensen, J.H., et al [9] from studies in which they used a Limulus assay technique for the detection of bacterial endotoxins. The concentration of endotoxins in the Blue Plains effluent is comparable to the concentrations in public drinking waters.

METALS

Data on the metals present in the influent and effluent are presented in Table 8 along with a list of the concentrations present in the Washington, D.C. drinking water, and the levels allowed in finished drinking water supplies as contained in the "EPA National Interim Primary Drinking Water Regulations", December 1975 [4]. None of the effluent samples taken exceeded metal concentrations cited in the EPA regulations. The reliability of the treatment system to meet these regulations is further demonstrated by the frequency distribution of effluent mercury for the second four month period of operation as shown in Figure 3. All twenty two of the data values were less than the 2 µg/l standard. The median value was 0.70 µg/l.

TABLE 4. VOLATILE ORGANICS

COMPOUNDS (All Units µg/l)	INFLUENT			EFFLUENT			*FINISHED DRINKING WATERS RANGE OF CONCENTRATIONS	DRINKING WATER WASHINGTON, D.C. (DELACARLIA PLANT)
	NUMBER OF SAMPLES	ARITH. MEAN	RANGE	NUMBER OF SAMPLES	ARITH. MEAN	RANGE		
Chloroform	14	13	4.44	12	8.0	<0.1-22	<0.1-311	41
Bromodi-chloro-methane	14	0.9	<0.1-4.5	12	5.4	<0.1-21	0.3-116	8
Dibromo-chloro-methane	14	5.9	<0.1-23	12	5.2	<0.1-28	<0.4-110	2
Bromoform	14	<0.1	<0.1-0.2	12	2.6	<0.1-23	<0.8-92	**N.D.
Carbon Tetra-chloride	13	5.6	<0.1-32	11	1.0	<0.1-5.2	<2-3	N.D.
1,2-Dichloro-ethane	14	9.7	<0.1-134	12	0.5	<0.1-2.6	<0.2-6	<0.3

*Based on 80 samples from National Organics Reconnaissance Survey - "Preliminary Assessment of Suspected Carcinogens in Drinking Water, Report to Congress", EPA, December 1975

**N.D. - None Detected

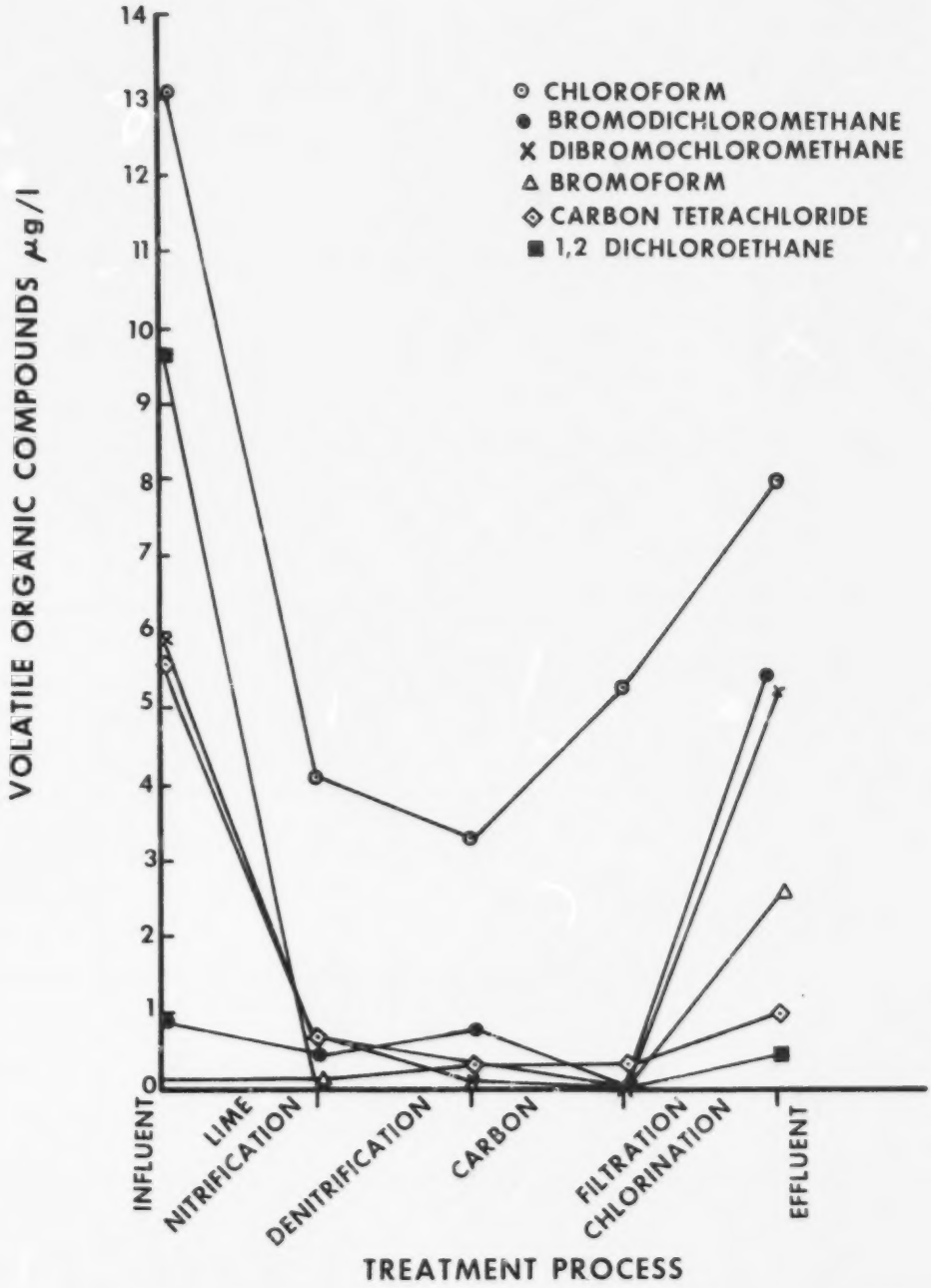

FIGURE 2. REMOVAL OF VOLATILE ORGANICS

TABLE 5. VOLATILE ORGANICS IN PROCESS EFFLUENTS

Compound (Unit µg/l)	Influent	Nitri-fication	Denitri-fication	Carbon	Chlorin-ation	Drinking Water**
Acetaldehyde	TR.*		TR.	TR.		✓
Methanol	TR.					✓
Acetone	TR.	TR.	TR.	TR.	TR.	✓
Dichloro-methane	4		TR.	1	TR.	✓
Acrolein	TR.		TR.		TR.	
Carbon Disulfide	TR.			TR.	TR.	✓
Chloroform	10	3	2	5	7	✓
Bromodichloro-methane	1	TR.			4	✓
1,1,1-Tri-chloroethane	TR.					✓
Chlorodi-bromoethane	4	TR.		TR.	2	✓
Benzene	2	1	1	1	2	✓

TABLE 5 (cont'd)

Compound (Unit µg/l)	Influent	Nitri-fication	Denitri-fication	Carbon	Chlorin-ation	Drinking Water**
Dimethyl disulfide	3					✓
Toluene	2	TR.	TR.	TR.	TR.	✓
N-Hexanol			TR.	TR.		
Tetrachloro-ethylene	3					✓
Xylene	TR.		TR.	TR.	TR.	✓
Alkyl benzene	TR.	TR.				
Benzaldehyde			TR.		2	✓
Carbon tetrachloride	2	TR.		TR.	TR.	✓

* TR. - Trace (<1 µg/l)

** "Preliminary Assessment of Suspected Carcinogens in Drinking Water," Report to Congress, EPA, Dec. 1975.

TABLE 6. MUTAGENICITY OF ORGANIC CONCENTRATES

R.O. Membrane and Solvent Fraction	*Mutagenic Potential
Cellulose Acetate	
• Pentane	**N.D.
• Methylene Chloride Neutral	N.D.
• Methylene Chloride Acidic	N.D.
Nylon	
• Pentane	N.D.
• Methylene Chloride Neutral	N.D.
• Methylene Chloride Acidic	N.D.
Composite	N.D.

* In Vitro with strains of salmonella typhimurium TA98 and TA100

** N.D. - None Detected

TABLE 7. RESULTS OF BACTERIAL ENDOTOXIN TESTING*

SOURCE	ENDOTOXIN EQUIVALENTS
	ng/ml
Blue Plains Reuse System	2.5 - 12.5
Public Drinking Water Systems	
1	1.25
2	12.5
3	2.5
4	12.5
5	0.625
6	500.0
7	125.0
8	10.0
9	2.5
10	2.5

*Limulus Assay Procedure - Jorgensen et al., Applied and Environmental Microbiology, September 1976.

TABLE 8. HEAVY METALS

Metal (Unit-µg/l)	Final Effluent			Washington, DC Drinking Water*	EPA Regulations**
	n	Arit. Mean	Range		
Mercury	47	0.666	0.100-1.25	<0.5	2
Cadmium	44	0.143	0.020-0.530	<2	10
Selenium	38	4.76	2.00-5.00	<5	10
Chromium	57	2.24	0.600-4.30	<5	50
Lead	53	0.308	0.030-1.07	<5	50
Manganese	60	7.96	1.40-20.0		
Arsenic	56	2.25	0.300-6.00	<5	50
Iron (mg/l)	227	0.0599	N.D.-0.810		
Barium	49	82.3	3.10-200	<50	1000
Copper	56	4.86	1.40-21.0		
Zinc	57	10.6	5.10-19.1		
Boron (mg/l)	8	0.313	0.300-0.400		

TABLE 8. (cont'd)

Metal (Unit-μg/l)	Final Effluent			Washington, DC Drinking Water*	EPA Regulations**
	n	Arit. Mean	Range		
Flouride (mg/l)	62	0.722	0.380-1.10	1.0	1.8 @ 65°F
Silver	49	0.134	0.009-0.400	<10	50
Cyanide	32	4.23	1.00-9.80	<20	
Aluminum (mg/l)	210	0.251	N.D.-0.900		

*"Preliminary Assessment of Suspected Carcinogens in Drinking Water" Report to Congress, EPA, December 1975.

**National Interim Primary Drinking Water Regulations, EPA, Federal Register, Vol. 40, No. 248, December 1975.

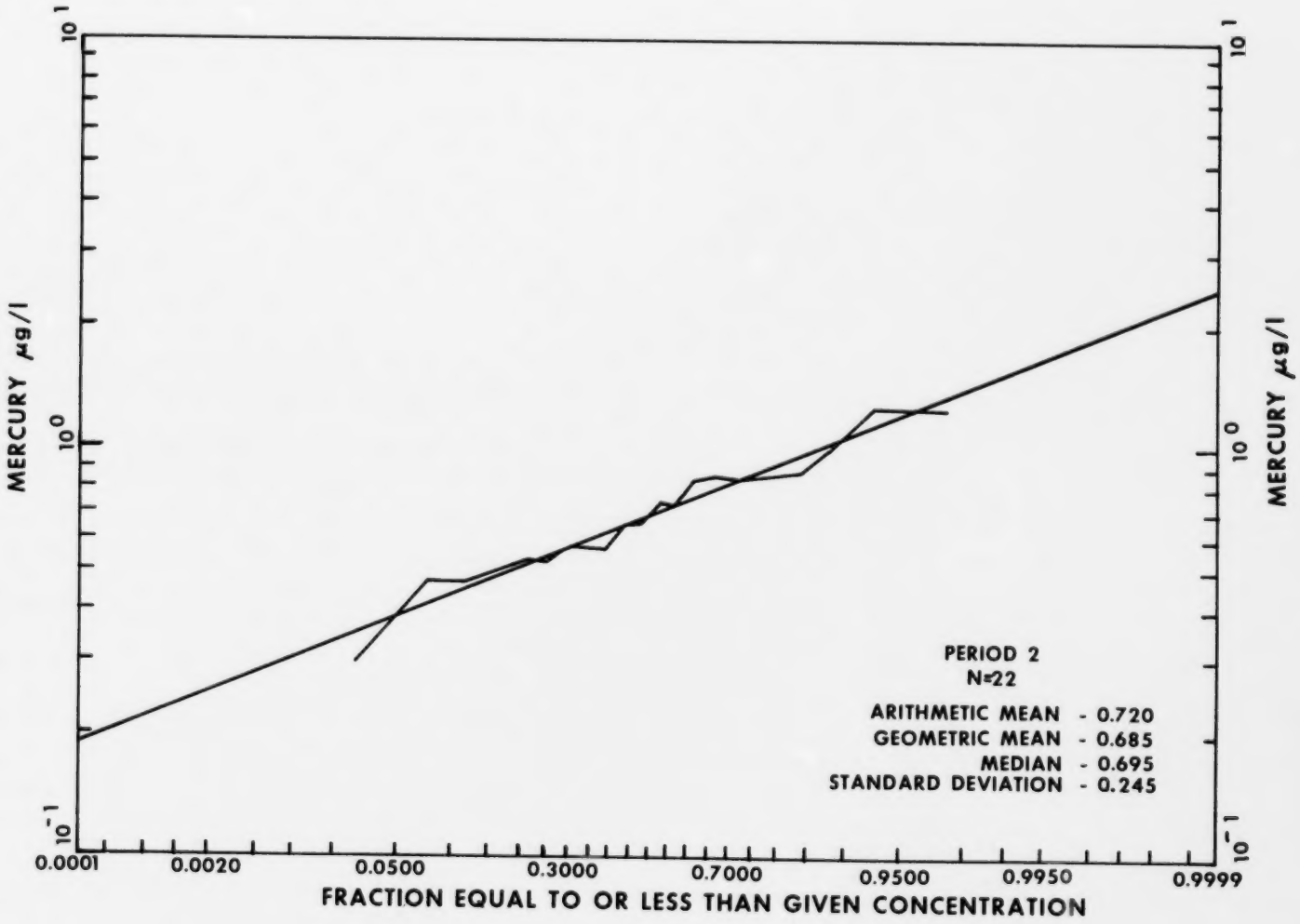

FIGURE 3. FREQUENCY DISTRIBUTION OF EFFLUENT MERCURY

In addition to determining metals in samples of the AWT system influent and effluent, the effluent from the lime clarification process was monitored for a four month period since previous data has shown that heavy metals can be removed by this process. Table 9 shows that concentration of metals in the influent, after the lime process, and in the final effluent. It is evident that the lime process is primarily responsible for the reduction in the metal concentrations.

PESTICIDES

Pesticide analyses were made on a less frequent basis than were analyses for metals. The data presented in Table 10 are based on samples taken twice per month. The levels in the effluent are significantly less than the EPA standards for drinking water that are listed in the table.

GENERAL ORGANICS

A summary of various gross measurements or organics in the influent and effluent is presented in Table 11 and includes the average of the parameters for a 14 month operation period. The treatment system is capable of reliably producing a high quality effluent on a continuous basis as evidenced by the TOC data presented in Table 12 and Figure 4. The 311 pieces of TOC data were grouped into 5 periods covering 18 months of operation and the arithmetic averages and standard deviations were determined. The average TOC in the finished drinking waters from 80 U.S. cities [5] is included in Table 12 for comparison purposes.

Figure 4 is a frequency distribution of 77 pieces of TOC data taken during the fifth and last period of operation. Included in the figure for comparison purposes is a frequency distribution of the TOC data from 80 drinking waters taken during the National Organics Reconnaissance Survey in 1975 [5]. The median TOC concentrations were 1.5 mg/l for the drinking waters and 2.5 mg/l for the wastewater effluent. The lower levels of TOC in the drinking water data may be attributed to the cities in the survey using groundwater supplies.

In an attempt to determine if additional TOC reduction was possible grab samples of effluent were ozonated on three separate occasions. An ozone dosage of 60 mg/l in the gas stream was introduced into a 1 liter sample using the reactor system described by Roan, S. [10]. The sample was reacted with the ozone stream for 60 minutes. The initial average TOC concentration was 1.21 mg/l and the final TOC was 0.84 mg/l which is a reduction of 30 percent. In addition, a short term side stream study was conducted using a strong acid cation resin in series with an intermediate base anion resin to determine the removal of the remaining TOC by ion exchange. These resins reduced the effluent TOC about 40 percent.

TABLE 9. HEAVY METAL REMOVAL BY LIME CLARIFICATION

Metal (Unit-μg/l)	Influent	Lime Clarification	Final Effluent
Mercury	0.813	0.931	0.802
Cadmium	1.92	-	0.143
Selenium	4.76	-	4.76
Chromium	16.9	5.59	3.18
Lead	23.4	0.682	0.399
Manganese	149	19.5	5.04
Arsenic	1.49	1.05	0.967
Iron (mg/l)	1.30	-	0.0467
Barium	54.3	34.3	27.2
Copper	48.9	7.72	5.66
Zinc	110	10.7	12.6
Boron (mg/l)	0.250	-	0.313
Fluoride (mg/l)	0.701	0.679	0.724
Silver	3.98	0.333	0.0987
Cyanide	5.80	-	4.23
Aluminum (mg/l)	-	-	0.251

TABLE 10. PESTICIDES

Pesticide Unit - ng/l (ppt)	Effluent**	*EPA Regulations
Aldrin	4	
DDT	10	
Dieldrin	1	
Endrin	5	200
Heptaclor	0.7	
Heptaclor Epoxide	1	
Lindane	2	4000
Methoxychlor	40	10^5
Diazin	5	
Guthion	200	
Malathian	10	
Parathian	10	

*EPA National Interim Primary Drinking Water Regulations, Federal Register, Vol. 40, No. 248, December 24, 1975

**Average of 4 data values for each pesticide

Table 11. GENERAL ORGANICS

PARAMETER	INFLUENT			EFFLUENT		
(units - mg/l)	N*	Arithmetic Mean	Standard Deviation	N	Arithmetic Mean	Standard Deviation
TOC	231	74.1	11.0	234	2.79	1.35
COD	229	240	30.5	226	6.53	3.12
BOD	245	106	15.7	221	3.12	2.15
MBAS	13	8.92	1.71	35	0.14	0.08
CCE	-	-	-	2	0.75	0.64
CAE	-	-	-	2	2.25	0.64
Phenol (µg/l)	9	12.9	4.02	54	3.66	1.52
UV @ 290 mµ (%T)	-	-	-	19	96.9	0.87

*N-number of samples

TABLE 12. VARIABILITY OF EFFLUENT TOC

4 Month Periods	Number of Samples	Arithmetic Mean (mg/l)	Standard Deviation
1	58	2.26	1.31
2	64	2.35	1.00
3	69	3.72	1.59
4	43	2.67	1.50
5	77	2.68	1.02
Total	311	2.76	-
*Finished Drinking Water	80	2.21	Range 0.05-12.2

*"Preliminary Assessment of Suspected Carcinogens in Drinking Water," Report to Congress, EPA, December 1975.

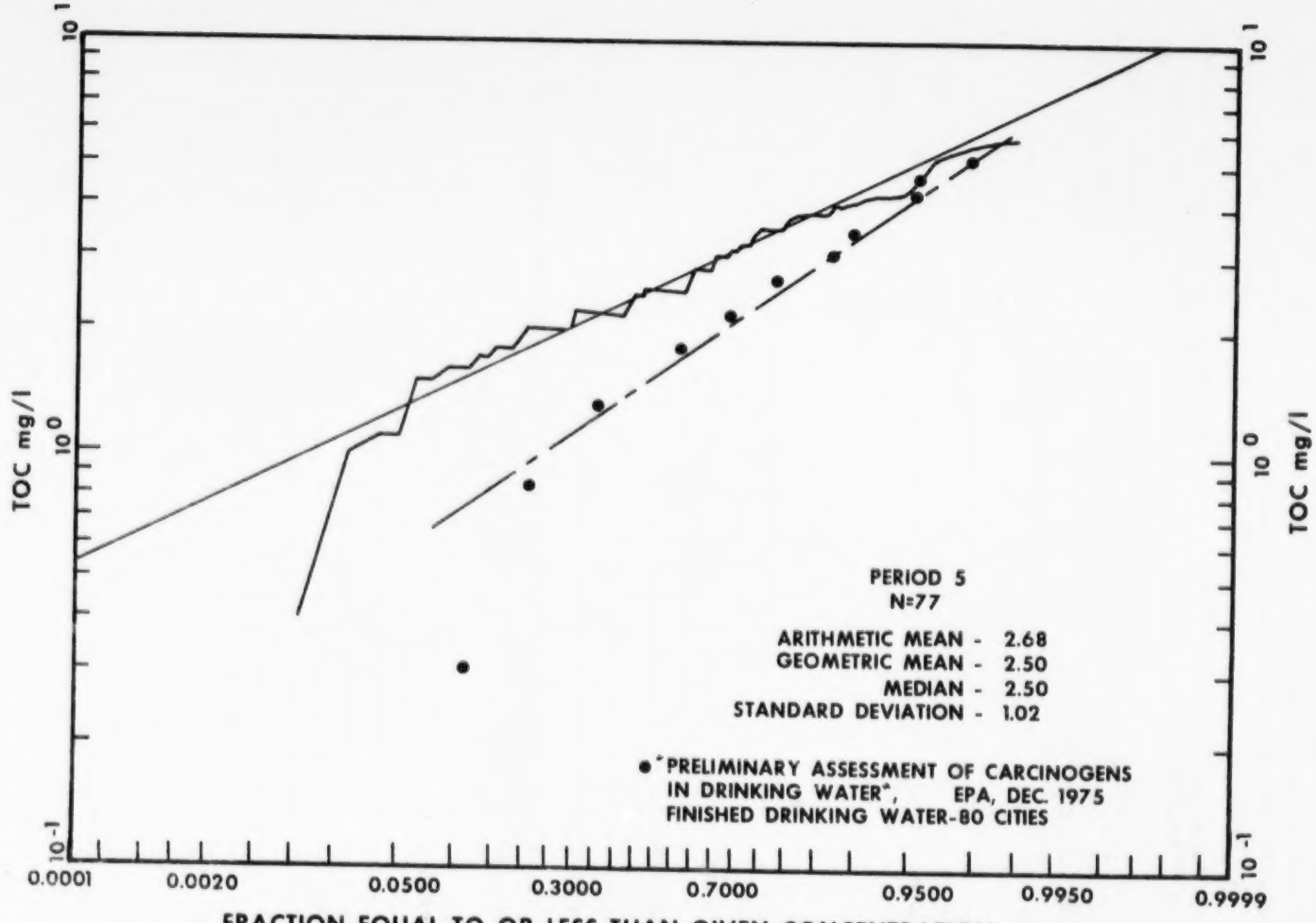

FIGURE 4. FREQUENCY DISTRIBUTION OF EFFLUENT TOC

Figure 5 shows a graph of the removal of TOC by each of the processes in the treatment system. Ninety-two percent of the TOC is removed in the lime clarification and nitrification processes. The increase in TOC in the denitrification process effluent is due to some leakage of methanol.

Table 13 shows the variability of the effluent COD for each of the five operating periods and Figure 6 shows a frequency distribution of 74 pieces COD data taken during the fifth operating period. The median COD value is 5.61.

GENERAL INORGANICS

A summary of the inorganic constituents in the influent and effluent is presented in Table 14. The arithmetic means and standard deviations of each constituent are shown. Samples of the effluent were checked for 80 elements by the Proton Induced X-ray Emission Procedure [11] to determine the presence of any unusual inorganic component. The results are shown in Table 15. No significant concentrations of hazardous inorganics were observed.

NUTRIENTS

The concentration of the phosphorus and nitrogen compounds are shown in Table 16. Over 200 pieces of data were used for each parameter in determining the means and standard deviations. No attempt was made to completely denitrify the effluent. The amount of methanol added to the denitrification process was based on allowing 2 to 4 mg/l of NO_3-N in the effluent.

SUSPENDED MATTER

Turbidity, and suspended and total solids data for the treatment system influent and effluent are shown in Table 17. The effluent turbidity level is within the requirements of the EPA National Interim Primary Drinking Water Regulations [4] which establishes the standard at 1 turbidity unit on a monthly average basis. The variability of the effluent turbidity is shown in Table 18. At the beginning of the last four months of operation (period 5) it was noted that the turbidimeter had not been properly standardized when making readings. Implementation of the correct standardization procedure accounts for the lower turbidity values during the fifth period. Figure 7 is a frequency distribution of the 332 turbidity values for samples taken in period five. Between 98 and 99 percent of the values were less than the standard of one. The median turbidity was 0.39 FTU.

MICROBIOLOGICAL AND DISINFECTION PARAMETERS

Data on the chlorine dosage, demand, and free residual in the effluent are included in Table 19 along with data on the concentration of various pathogenic indicator organisms. The free residual chlorine concentration of 2.23 mg/l and low turbidity of 1 FTU have combined to produce an effluent that consistently meets the EPA Drinking Water Regulations.

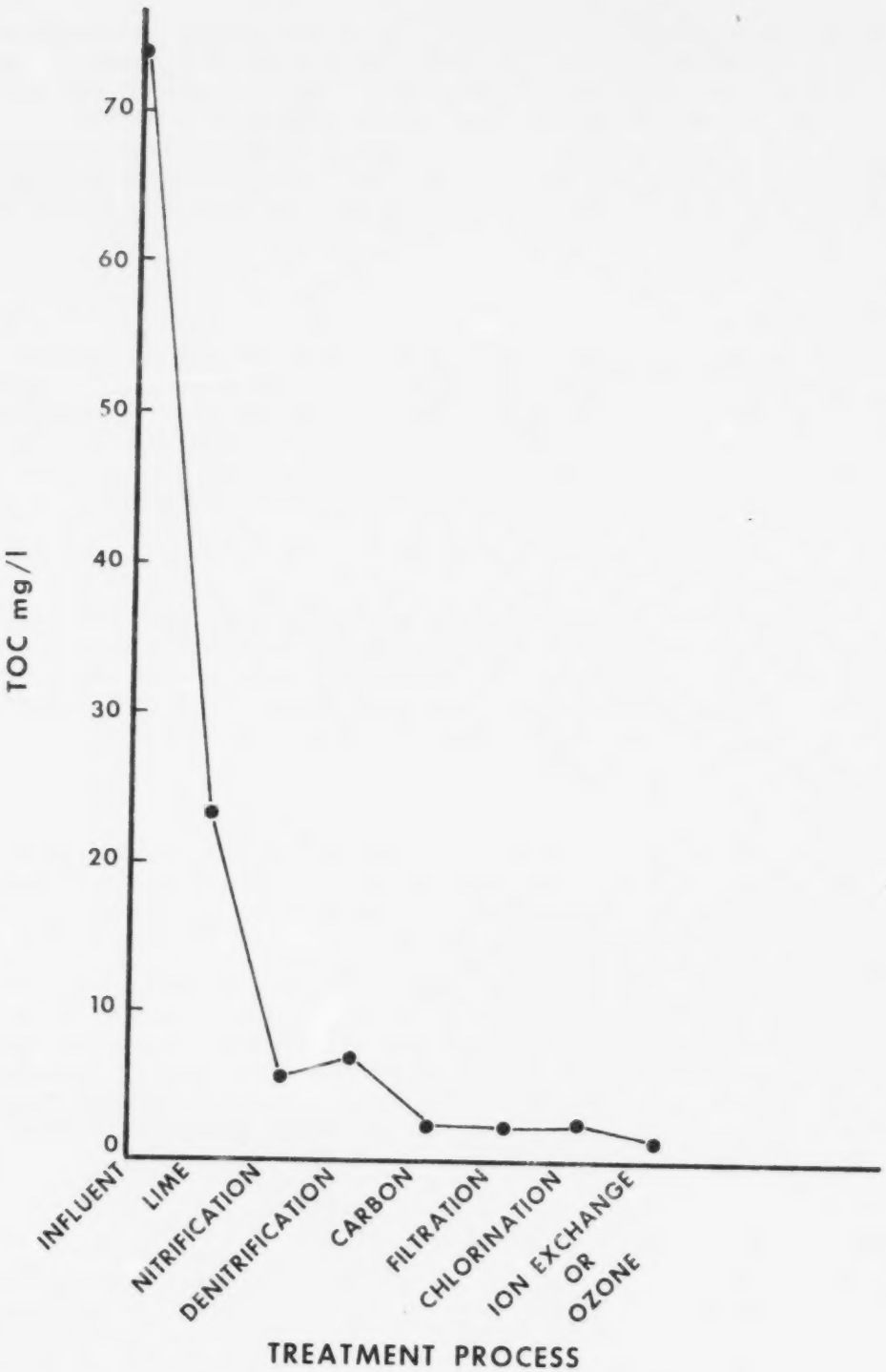

FIGURE 5. REMOVAL OF TOC

TABLE 13. VARIABILITY OF EFFLUENT COD

4 Month Periods	Number of Samples	Arithmetic Mean (mg/l)	Standard Deviation
1	58	5.28	2.55
2	64	5.96	3.09
3	67	7.64	2.54
4	37	7.45	3.29
5	74	6.25	2.20
Total	300	6.45	-

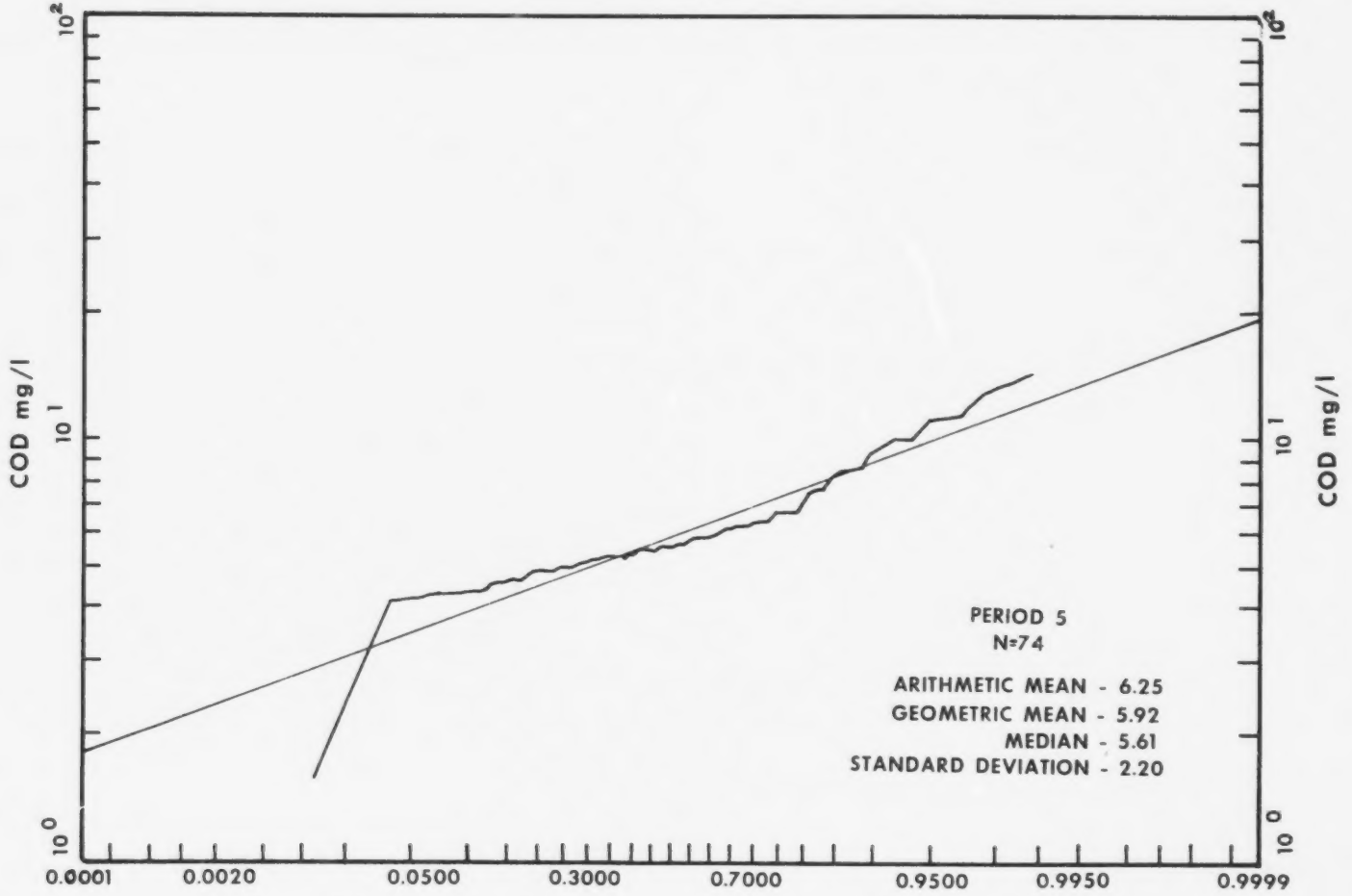

FIGURE 6. FREQUENCY DISTRIBUTION OF EFFLUENT COD

TABLE 14. GENERAL INORGANICS

PARAMETER	INFLUENT			EFFLUENT		
(unit - mg/l)	N*	Arithmetic Mean	Standard Deviation	N	Arithmetic Mean	Standard Deviation
pH	2274	7.20	0.118	1081	7.34	0.146
Total Alkalinity	2435	125	15.1	980	102	12.1
Conductivity (μmhos/cm)	-	-	-	830	514	36.0
TDS	137	283	28.6	210	357	31.6
Hardness	35	115	7.65	40	162	7.18
$CaCo_3$ Stability	-	-	-	40	0.198	0.394
Chloride	-	-	-	158	68.6	4.56
Sulphate	-	-	-	122	50.1	3.83
Calcium	176	31.2	2.73	218	56.6	4.40
Magnesium	178	6.47	0.579	224	5.49	0.481
Sodium	-	-	-	228	34.1	2.94
Potassium	-	-	-	21	8.23	0.318

* N-number of samples

TABLE 15. RESULTS OF 80 ELEMENT SURVEY*

Elements Detected in Effluent (mg/l)		
Na - 37.8	Zn - 0.017	Ba - 0.034
K - 7.08	Cd - 0.002	As - 0.006
Ca - 54.0	I - 0.013	NI - 0.004
V - 0.003	Pb - 0.003	Cu - 0.013
Cr - 0.001	Ga - 0.001	Sr - 0.151
Fe - 0.031	Br - 0.100	Sn - 0.002
Co - TR.	Rb - 0.007	S - 2.85

Elements Not Detected (mg/l)
Mn, Mo, Ag, Sc, Ti, Ge, Y, Pd, In, Sb, Te, Cs, La, W, Pt, Tl, Bi, Si, P, Ar, Se, Kr, Zr, Nb, Ru, Rh, Xe, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Re, Os, Ir, Au, Hg, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U, Np, Pu

*Proton - Induced X-Ray Emission Procedure

TABLE 16. NUTRIENTS

PARAMETER	INFLUENT			EFFLUENT		
(unit - mg/l)	N*	Arithmetic Mean	Standard Deviation	N	Arithmetic Mean	Standard Deviation
TPO_4	244	15.1	2.19	232	0.153	0.09
TKN	128	19.0	2.50	98	0.222	0.17
NH_3-N	243	17.5	2.32	223	0.069	0.15
NO_3+NO_2-N	232	0.095	0.08	229	3.84	1.84

* N-number of samples

TABLE 17. SUSPENDED MATTER

PARAMETER	INFLUENT			EFFLUENT		
(unit - mg/l)	N*	Arithmetic Mean	Standard Deviation	N	Arithmetic Mean	Standard Deviation
Turbidity (FTU)	-	-	-	1395	0.884	0.448
Suspended Solids	241	109	21.3	225	1.02	0.954
Volatile Suspended Solids	294	84.0	16.0	-	-	-
Total Solids	-	-	-	209	362	30.4

* N-number of samples

TABLE 18. VARIABILITY OF EFFLUENT TURBIDITY

4 Month Periods	Number of Samples	Arithmetic Mean (FTU)	Standard Deviation
1	161	0.730	0.256
2	262	0.885	0.800
3	313	1.06	0.464
4	327	1.26	0.520
5	332	0.418	0.182
Total	1395	0.884	-

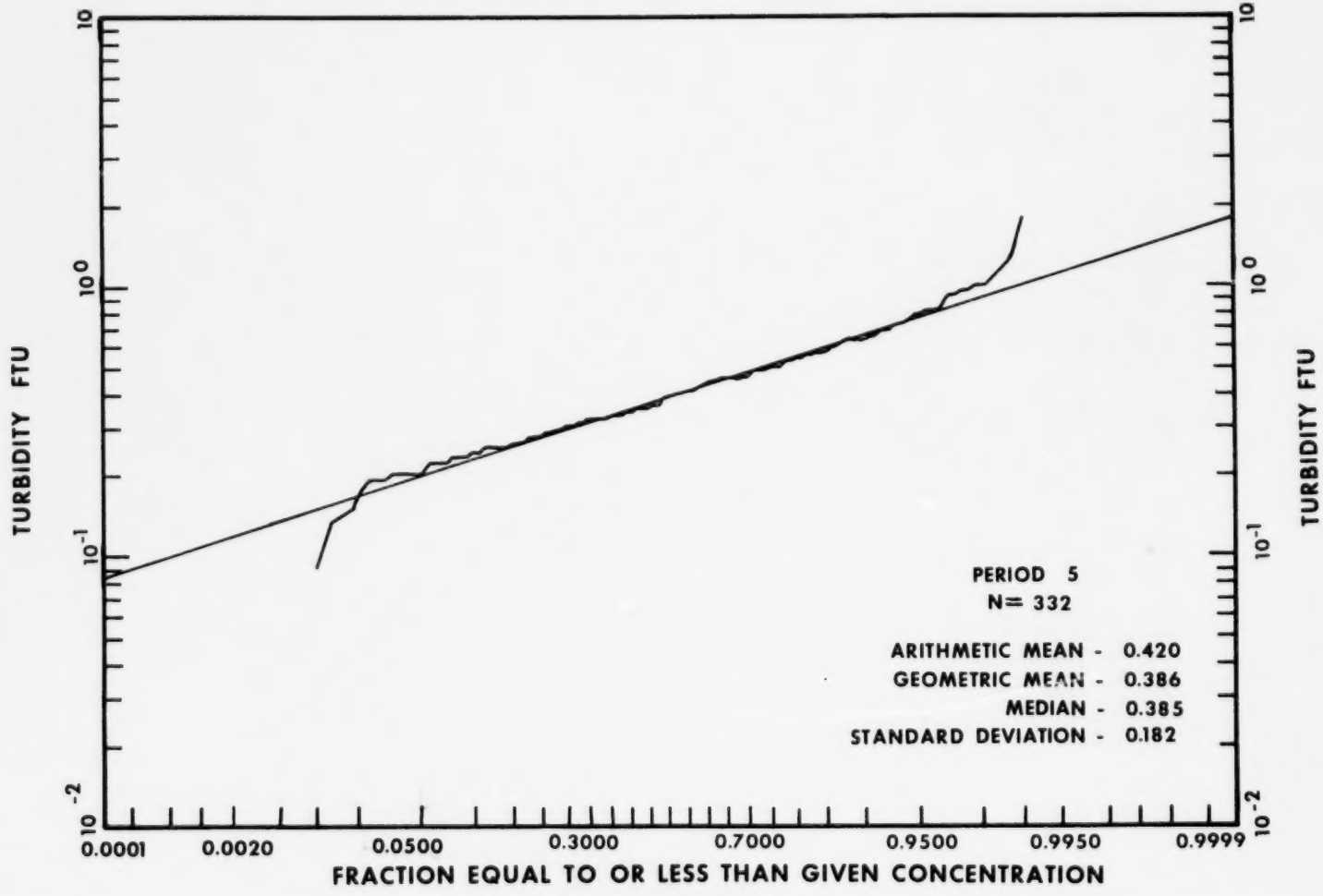

FIGURE 7. FREQUENCY DISTRIBUTION OF EFFLUENT TURBIDITY

TABLE 19. MICROBIOLOGICAL AND DISINFECTION PARAMETERS

PARAMETER	EFFLUENT		
	N*	Arithmetic Mean	Standard Deviation
Chlorine Dosage mg/l	2030	4.35	-
Chlorine Demand mg/l	43	1.83	1.62
Chlorine Residual (free) mg/l	57	2.23	1.45
Total Coliforms cells/100 ml	114	0.11	0.39
Fecal Coliforms cells/100 ml	119	0.17	0.50
Pseudomonas Aeruginosa cells/100 ml	36	0.81	1.53
Salmonella cells/100 ml	40	0	0
Total Count cells/100 ml	44	66.8	42.3

*N-Number of samples

ESTHETIC PARAMETERS

The effluent had no odor when compared to samples of odor free water prepared for the threshold odor test, and exhibited a level of color equal to 3.5 color units based on the platinum - cobalt standard. This data along with the average influent and effluent temperature are shown in Table 20.

TABLE 20. ESTHETICS

PARAMETER	INFLUENT			EFFLUENT		
	N*	Arithmetic Mean	Standard Deviation	N*	Arithmetic Mean	Standard Deviation
Temperature (°C)	382	20.9	2.50	320	22.0	2.32
Odor (TON)	-	-	-	35	**N.D.	N.D.
Color (P-C units)	-	-	-	84	3.52	0.37

*N-number of samples

**N.D. - none detected

SECTION 5

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